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The Use of Carbon Dioxide as a Supplement to Refrigeration in the Express Transportation of Sweet Cherries

Report of investigations made in cooperation with the Division of Pomology, California Agricultural Experiment Station

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Introduction

Previous investigations on the use of carbon dioxide in the storage and transportation of sweet cherries have been reported in U. S. Technical Bulletin 671, H. T. & S. Office Reports No. 25 and No. 31, and in the Proceedings of the American Society for Horticultural Science, Vol. 37, 1939. The reports on the use of gas treatments in transit are concerned entirely with the movement of sweet cherries by freight from the Northwest to eastern markets. Since the movement of California cherries to market is very largely by railway express, questions have arisen as to the usefulness and practicability of carbon dioxide as an adjunct to refrigeration in express shipments.

The present investigation was planned to secure information on the following points: (1) Gas retentiveness of express refrigerator cars, (2) Effect of express train speed upon maintenance of CO_2 concentrations, (3) Possible benefits to the fruit of CO_2 during the relatively short transit period of express shipments and (4) The effects of CO_2 concentrations in cars upon the development of fruit rots, particularly brown rot (Sclerotinia fructicola and S. laxa).

Outline of Tests

The principal shipping points for sweet cherries in California are Stockton in the upper San Joaquin Valley and Santa Clara in the Santa Clara Valley. Since growing conditions and handling methods differ considerably in the two districts, several shipping tests were made from each point.

Each shipping test consisted of two cars, both loaded the same day under as nearly comparable conditions as possible. Both cars were shipped to New York and sold on the auction the same morning. An attempt was made to secure two comparable express cars of the same series for the test shipments although this was not always possible. In every case the cars which appeared to be in the best condition with regard to inside walls, doors and hatch plugs were selected from those available.

Some unavoidable variation was encountered between test loads in precooling temperatures, size of load and refrigeration in transit. These data are shown in the loading and transit temperature records and allowance can be made for them in interpreting the final results.

Each test consisted of one CO_2 treated car and one check car. Immediately after loading and bracing had been completed the CO_2 car was charged by placing approximately 1000 pounds of dry ice (50 pound cakes in sealed double paper bags) in a special crate on the top horizontal pieces of the bracing at the center of the car. The crate was constructed and placed in the bracing in such a manner as to hold the dry ice at least 6 to 8 inches away from the nearest fruit packages. After the car doors were closed dry ice was added to each bunker in amounts varying from 30 to 90 pounds and broken up on top of the water ice.

A copper tube was placed in each CO_2 car so that samples of the atmosphere could be withdrawn for analysis. The point of sampling was about

twelve inches back in the doorway stack and about twelve inches above the floor racks.

Loading data, fruit temperatures, precooling methods and the quantity of dry ice used are shown in Tables 1 and 2.

Table 1. Shipping tests - Stockton, Calif. to New York - Car precooled with bunker fans.

Table 2. Shipping tests - Santa Clara, Calif. to New York - Fruit precooled in storage.

Test boxes

In order to evaluate more accurately the effect of CO_2 on fruit color, condition, and the development of decay, comparable test boxes of fruit were placed in the top layer doorway stack of each of the two test cars in each shipment. Fruit for these test boxes was selected and packed in the orchard. Where possible, two maturities of the same variety were selected from the orchard as the fruit was brought in by the pickers. The fruit was selected on the basis of color, being divided into "reds" and "darks". The "reds" varied from light red to pie-cherry red while the "darks" ranged from dark red to dark mahogany. No whitish or pink fruit was included among the "reds" and no black fruit was used in the "darks". Black Tartarians were used for test fruit in the early season shipping tests and Bings in the later tests. Soluble solids of the test fruit as determined by a Zeiss hand refractometer averaged 16.2 percent for the dark Tartarians and 13.2 percent for the red Tartarians while the dark and red Bings averaged 22.1 percent and 16.5 percent respectively.

One box of each maturity for each car was packed with the standard double-face pack in Campbell lugs. Fruit sufficient to pack another box of each maturity for each car was then inoculated by shaking the fruit on emery paper and dusting with brown rot spores (Sclerotinia fructicola and S. laxa). The inoculated fruit was then loose-packed in Campbell lugs and placed in the test cars.

Test boxes for the shipments from Santa Clara were prepared the day previous to loading and stored at 32° F. immediately after packing since the commercial lots of fruit were handled in this manner. The test boxes for shipments originating in Stockton were prepared before noon on the day of loading, and placed in the car warm in the early evening according to commercial practice. The load was then precooled from 15 to 22 hours in the car by means of fans at the upper bunker openings.

Holding tests

As a part of the study to determine the effect of carbon dioxide upon the development of brown rot and general market condition, comparable samples of fruit were held in air and in carbon dioxide atmospheres at 42° in the University Farm cold storage at Davis.

The holding tests included both Black Tartarian and Bing varieties. All fruit was carefully selected for uniformity of color, each test usually including the two maturities of fruit used in the shipping tests. The cherries were face-and-fill packed in lugs and were comparable in every other respect to commercial shipments and to the test boxes which were actually shipped.

The fruit was examined for color and firmness at the time of packing and then placed in atmospheres of normal air and in carbon dioxide and held at 42° for ten days. Upon removal from storage, additional observarions were made and the percentage of decay in each sample of fruit was recorded. A similar observation and a second count of decay was again made two days later.

The fruit held in carbon dioxide atmospheres was placed in air-tight cabinets and the gas concentration used was derived from dry ice. During the first day of holding the concentration of CO_2 ranged from a minimum of 10% in one test to a maximum of 23% in another. Each day the cabinets were ventilated slightly so that at the end of the ten-day period the carbon dioxide concentration had been reduced to between 4% and 7%. This procedure was carried out to simulate the conditions which normally might be expected in refrigerator cars during shipment to Eastern markets.

Before storing the fruit, portions of each sample were dusted with spores of S. fructicola. It was found, however, that this inoculation failed to produce any more infections than were shown by fruit which was not artificially inoculated.

Transit temperatures

A recording thermometer was placed in each car immediately after loading in order to obtain a record of the air temperature during precooling and in transit. In each car the thermograph was placed on the side wall of the car about 8 inches back of the doorway and a few inches above the top layer of the load. By this means, a record of the air temperature in transit was obtained at one of the warmest points.

Results

Carbon dioxide concentrations

Carbon dioxide concentrations obtained at shipping point and at arrival in New York are shown in Table 3.

Table 3. Carbon dioxide concentration in test cars.

It was not always possible to secure readings over a long enough period to determine the peak concentration. The data indicate, however, that the highest concentration was obtained 4 to 5 hours after charging and was maintained at least through seven hours after charging. Maximum concentrations five hours after charging ranged from 20 to 24 percent in the three cars checked. Samples obtained from two of the cars in Chicago indicated that leakage from the cars was greater than the CO_2 output from the dry ice within the car as the concentration had dropped to 10 percent and 7.5 percent respectively after approximately 80 hours. Concentrations found in New York before the cars were opened ranged from 6 to 8.2 percent and from 150 to 250 pounds of dry ice remained in the container at the time the cars were unloaded.

Temperatures in transit

Air temperatures during the precooling and transit periods for the two cars in Test 1 are shown in Figure 1.

Figure 1. Temperatures during precooling and transit. Test 1 - Stockton to New York

The curves show that precooling temperatures were about equal. The check car B was subjected to somewhat longer precooling and was shipped with 3 percent salt compared with 2 percent salt for the CO_2 car. The influence of these factors is reflected in the slightly lower air temperatures during transit for the check car.

Air temperatures during transit for the two cars in Test 2 are shown in Figure 2.

Figure 2. Temperatures during transit. Test 2 - Santa Clara to New York.

As shown by the temperature curves, there was no significant difference in air temperatures in the two cars during the transit period.

In Figure 3 are shown the precooling and transit temperatures recorded in the two cars of Test 3.

Figure 3. Temperatures during precooling and transit. Test 3 - Stockton to New York.

While the curves show a somewhat lower air temperature for the CO_2 car during the precooling period the air temperatures during that part of the transit period shown for both cars are again similar. The record for Car B is incomplete due to failure of the recording thermometer.

Temperatures recorded during precooling and transit for Test 4 are shown in Figure 4.

Figure 4. Temperatures during precooling and transit. Test 4 - Stockton to New York.

The CO_2 car was precooled to somewhat lower temperatures than the check car and this is reflected in significantly lower air temperatures in the former during transit. The air temperature was consistently 6 to 8 degrees lower in Car A than in Car B throughout the transit period. Since both cars were shipped under standard refrigeration with 2 percent salt it is difficult in the light of the results secured in tests 1, 2, and 3, to explain why the air temperatures remained so far apart throughout the entire period.

Figure 5 shows the air temperatures found in Test 5.

Figure 5. Temperatures during transit. Test 5 - Santa Clara to New York.

The temperature advantage was again with the CO_2 car although the difference in temperature during most of the period was only 3 to 4 degrees. It is possible that the presence of the dry ice in the CO_2 cars affected the air temperature somewhat at the position where the record was taken (near the top doorway). The recording thermometer was 12 to 16 inches away from the nearest dry ice and previous experiments indicated that dry ice at the bracing has only a minor effect upon temperature at this point.

Effects on fruit

Records obtained in New York on the condition of the fruit in test boxes placed in the CO_2 and check cars of Test 1 are shown in Table 4.

Table 4. Condition of fruit in test boxes after unloading. Test 1

The first examination of this fruit was made 8 hours after unloading. As indicated in the footnote to Table 4, the test fruit from the check car was slightly darker than that from the CO_2 car. No difference was found in the condition or color of the stems. The detailed inspection including decay counts

was made 48 hours after the first inspection or 56 hours after unloading. As shown in the table the decay was very serious at this time and it was decided that in subsequent tests the detailed examination should be made 36 hours after unloading.

The results indicated that there was a large amount of decay from natural infection, mostly brown rot, as the test fruit which was artificially inoculated generally did not show more decay than the fruit which was packed just as it came from the orchard. Since there was no consistent difference in decay as a result of inoculation, the average decay found in the two boxes of comparable maturity is shown in the table.

The results shown in Table 4 indicate that even after 56 hours the decay was somewhat less in fruit from the CO_2 car although it was serious in all the lots. Fruit of the "red" maturity showed only about one third as much decay as that of the "dark" maturity after 56 hours at room temperature.

Results of the examination of the fruit in Test 2 are shown in Table 5.

Table 5. Condition of fruit in test boxes after unloading. Test 2.

As noted in the table no difference in color of fruit or stems was discernable 8 hours after unloading. After 36 hours the only difference between fruit from the CO_2 and check cars was in the amount of decay. Dark fruit from the CO_2 car averaged 18.2 percent decay while comparable fruit from the check car showed 21.8 percent decay. The "red" lots averaged 6.8 and 10.9 percent respectively. All of the decay found was brown rot.

Table 6 shows the results of fruit inspection obtained in Test 3.

Table 6. Condition of fruit in test boxes after unloading. Test 3.

Only fruit of the "red" maturity was available for this test as the harvest of the Bing variety had just started. Results are shown for the non-inoculated and the inoculated lots of "red" fruit used. After 8 hours at room temperature no difference in fruit or stem color was noted between fruit shipped in the treated and untreated cars. Decay counts made after an additional day at room temperature showed an average of 1.8 percent decay for both inoculated and non-inoculated fruit from the CO_2 car whereas comparable lots from the check car showed 4.9 percent decay for the non-inoculated fruit and 8.7 percent decay for the inoculated.

The condition of Bing cherries in the test boxes shipped in Test 4 are shown in Table 7.

Table 7. Condition of fruit in test boxes after unloading. Test 4.

Eight hours after removal from the cars the "darks" from the CO_2 car were slightly lighter in color than those from the check car and the "red" fruit was found to be definitely lighter. No difference was noted in stem color or condition which could be attributed to the carbon dioxide.

After 36 hours at room temperature the "dark" Bings from the CO_2 car averaged 12.9 percent decay while "darks" from the check car showed 22.1 percent. The "red" lots after the same interval showed 1.1 and 1.9 percent decay respectively.

In Table 8 are shown the results of fruit examinations obtained in Test 5.

Table 8. Condition of fruit in test boxes after unloading. Test 5.

This test fruit was obtained when Black Tartarian cherries were being "cleaned up" in the Santa Clara Valley and the harvest of Bings had not begun. Consequently only "dark" Tartarians were secured for the test boxes. Results are shown for both inoculated and non-inoculated fruit.

The results show that faced fruit in the CO_2 car was slightly lighter in color after unloading than comparable fruit from the check car. No difference in stem color was noted but the inoculated fruit from both cars was found to have stems somewhat more wilted after 36 hours than the non-inoculated fruit. This difference was probably due to abrasion of the stems during the inoculation process.

After 36 hours at room temperature, test fruit from the check car showed two or three times as much decay as that from the CO_2 car. For some unexplainable reason the non-inoculated fruit showed significantly more decay than the inoculated.

Holding tests in California

Results obtained in the holding tests at Davis are shown in Table 11.

Table 11. Results of holding tests with Black Tartarian and Bing cherries in carbon dioxide to simulate transit conditions.

The results secured in these tests with carbon dioxide for the control of decay closely paralleled those secured in the shipping tests. In most instances, there was less decay after 10 days in lots of fruit which had been held in carbon dioxide atmospheres. After two additional days of holding, the results were less consistent, but decay had increased materially in almost all lots.

At the concentrations used, the carbon dioxide had no consistent effect upon color development although in some cases the treated fruit was slightly lighter than the untreated. It was noted, however, in practically all instances that the fruit held in carbon dioxide was slightly firmer and was of brighter appearance and seemed to possess more "life" than the samples held in air.

Effect on auction price

During the course of these tests there was an opportunity to compare prices on comparable lots of fruit in CO_2 and check cars. Certain lots of fruit packed by growers from their own orchards were divided between the test cars and sold on the same morning on the New York auction. Since the fruit was entirely comparable at the time of loading it is reasonable to assume that any difference in price was the result of transit conditions.

Price comparisons on comparable grower lots and row sizes in Tests 3 and 4 are shown in Tables 9 and 10.

Table 9. Auction prices of comparable lots. Shipped 5/21/41, Sold 5/26/41.

Table 10. Auction prices of comparable lots. Shipped 5/23/41, Sold 5/28/41.

These data show a significant price difference in favor of cherries shipped under CO_2. The weighted averages in Table 9 show a difference ranging from $.20 to $.49 per box for both Bings and Black Tartarians. In Table 10 the weighted averages range from $.10 to $.22 per box higher for the fruit from the CO_2 car. The fact that the CO_2 was placed in the car of shipper A in the first comparison and in the car of shipper B in the second comparison eliminated the possibility that brand reputation was responsible for the difference in the price.

Discussion and Summary

The few carbon dioxide concentrations measured during transit indicate that a maximum concentration of 20 to 24 percent was obtained and that this was gradually reduced so that concentrations were down to 6 to 8.5 percent before unloading in New York. Leakage from the cars was so great that the CO_2 given off by the charge of solid carbon dioxide at the bracing was not sufficient to maintain optimum concentrations throughout the transit period. From these results and judging from earlier work done in the Pacific Northwest,

it would seem that California shippers should use at least 1000 to 1100 pounds of solid carbon dioxide in express refrigerator cars to obtain benefits commensurate with the added expense of the CO_2 treatment.

Air temperatures at the top doorway position of the test cars usually ranged from 40°to 50°F. In two of the tests air temperatures were about the same in the check and CO_2 cars; in one test the check car was colder than the CO_2 car and in two tests the CO_2 car was the colder.

Fruit in the test boxes was in some cases lighter in color as a result of the CO_2 in transit. In other tests no difference in color was discernable. It is probable that during the relatively short transit period of express shipment there was little change in fruit color in either the check or treated cars. No difference in stem color or freshness as a result of the CO_2 treatment was noted in any of the test shipments.

The amount of decay after 36 hours at room temperature following transit was consistently less in fruit from the CO_2 cars than in that from the check cars. Most of the decay was brown rot which was very prevalent in the California cherry districts during the present season. The results indicate that the concentrations of CO_2 obtained had a distinctly inhibiting effect on the development of brown rot.

The "red" fruit included in the test cars developed consistently and significantly less decay than the "dark" fruit. The weather conditions, however, were very favorable for the development of decay, and injury to the fruit from rain cracking and wind bruising made it very susceptible to fungal invasion. However, these tests do not indicate that the dark fruit could not be marketed satisfactorily in a season when weather conditions were more nearly normal.

Comparisons of auction prices on grower-packed fruit show that the cherries carried in express refrigerator cars containing carbon dioxide sold on the New York market for prices ranging from $.10 to $.49 per box more than those carried in untreated cars. This is more convincing evidence than the reduction in decay found in the test fruit and indicates the value of using solid carbon dioxide in express shipments of sweet cherries. If refrigerator cars were available which are more retentive of carbon dioxide, the value of the treatment would be increased and its cost would be less because smaller quantities of solid carbon dioxide could be used.

Table 1. Shipping tests - Sweet cherries - 1941
Stockton, California to New York - Car precooled with bunker fans

Car No.	Date loaded	Loading begun	Loading finished	Fruit temp. F at loading	Precooling record			Date shipped	Refrigeration in transit	Pounds of dry ice	
					Hours fans operated	Minimum Temp. air blast	Fruit* temp. when fans out			At Bracing	In Bunkers
P.F.E. 716	May 14	7 pm.	10 pm.	68°- 72°	15	30°	32°	May 15	Standard ref. 2% salt	950	165
P.F.E. 520	May 14	7 pm.	9 pm.	68°- 70°	22	30°	32°	May 15	Standard ref. 3% salt	None	None
P.F.E. 668	May 20	6:30 p.	10:30 p.	76°- 78°	14.5	29°	35°	May 21	Standard ref. 2% salt	935	185
R.E.X. 362	May 20	6:00 p.	11:30 p.	78°-82°	17.0	31°	42°	May 21	Standard ref. 2% salt	None	None
M.P. 3208	May 22	6:00 p.	10:15 p.	77°-82°	15.0	31°	35°	May 23	Standard ref. 2% salt	1028	102
M.P. 3201	May 22	8:30 p.	11:50 p.	78°-82°	16.5	31°	41°	May 23	Standard ref. 2% salt	None	None

* Fruit temperature taken at top doorway centerline.

Table 2 Shipping tests - Sweet Cherries - 1941
San Jose, California to New York - Precooled in storage room

Car No.	Date loaded	Loading begun	Loading finished	Fruit temp. at loading	Car temp. at loading	Date shipped	Refrigeration in transit	Pounds of dry ice	
								At Bracing	In Bunkers
P.F.E. 527	May 18	2:30 p.	5:30 p.	37°-38°-38° 60°-60° 1/	56°	May 18	Standard ref. 2% salt	800	120
P.F.E. 522	May 18	2:30 p.	4:00 p.	36°-36°-37°	48°	May 18	Standard ref. 2% salt	None	None
P.F.E. 785	May 24	4:00 p.	5:30 p.	34°-38°-38° 41.5°-43° 2/	51°	May 24	Standard ref. 2% salt	1020	102
M.P. 3363	May 24	1:00 p.	3:00 p.	42°-43°-38° 67°-64° 3/	50°	May 24	Standard ref. 2% salt	None	None

1/ 300 boxes non-precooled fruit loaded.
2/ 300 boxes precooled for only three hours.
3/ 150 boxes non-precooled fruit.

Table 3. Carbon Dioxide Concentration in Test Cars moving by express - California to New York - 1941

Test No.	Car No.	Shipping point	Pounds dry ice		Percent carbon dioxide								
					At shipping point - Hours from charging							At Chicago 1/	At New York 2/
			At Bracing	In Bunkers	1/2	1	2	3	4	5	7		
1	P.F.E. 716	Stockton	950	165	8.0	12.5	17.5	20.5	22.5	22.5	--	--	7.5
2	P.F.E. 527	Santa Clara	800	120	9.0	12.0	14.5 3/	--	--	--	--	10.0	7.0
3	P.F.E. 668	Stockton	935	135	12.0	16.0	21.0	23.0	--	24.0	24.0	7.5	6.0
4	M.P. 3208	Stockton	1028	102	9.0	11.5	15.0	17.0	19.0	20.0	20.0	--	8.2
5	P.F.E. 785	Santa Clara	1020	102	9.0	12.0	--	--	--	--	--	--	6.6

1/ About 80 hours after charging.

2/ About 106 hours after charging.

3/ 1 1/2 hours after charging.

Table 4. Condition of Black Tartarian Cherries in test boxes shipped in test 1, Stockton to New York

Car	Test Fruit	Fruit temperatures at unloading °F: Position	Doorway	Quarter length	Bunker	1st inspection. After 8 hours. 2/ Fruit color	Condition: Fruit	Condition: Stems	2nd inspection. 48 hours after first inspection. Fruit color	Condition: Fruit	Condition: Stems	Average percent decay 1/: Brown rot	Green mold	Rhizopus	Total
P.F.E. 716 Carbon dioxide	Dark	top	43	43	43	Reddish Dark	Bright	Green Fresh	Reddish Dark	Bright	Green	45.0	2.8	1.8	49.6
		bottom	39	41	--										
	Red					Red	Ditto	Ditto	Red	Ditto	Ditto	11.8	1.8	.9	14.5
P.F.E. 520 Check untreated	Dark	top	43	46	46	Reddish Dark	Bright	Green Fresh	Reddish Dark	Bright	Green	51.5	4.3	4.3	60.1
		bottom	39	39	--										
	Red					Red	Ditto	Ditto	Red	Ditto	Ditto	15.0	1.5	.3	16.8

1/ Average of four 5-pound samples taken from two packed boxes; one box inoculated, one box non-inoculated

2/ In each lot the fruit from PFE 520 was slightly darker than that from PFE 716.

Table 5. Condition of Black Tartarian Cherries in test boxes shipped in Test 2, San Jose to New York

Car	Test Fruit	Fruit temperatures at unloading °F: Position	Doorway	Quarter length	Bunker	1st inspection. After 8 hours: 2/ Fruit color	Condition: 3/ Fruit	Stems	2nd inspection, 36 hours after unloading: Fruit color	Condition: 3/ Fruit	Stems	Average percent decay 1/: Brown rot	Green mold	Rhizopus	Total
P.F.E. 527 Carbon dioxide	Dark	top	43	47	--	Reddish dark	9	Green Fresh	Dark	33	Green Fresh	18.2	None	None	18.2
		bottom	38	35	--										
	Red					Dark red	4	Ditto	Dark red	25	Ditto	6.8	None	None	6.8
P.F.E. 522 Check untreated	Dark	top	43	45	--	Reddish dark	15	Green Fresh	Dark	57	Green Fresh	21.8	None	None	21.8
		bottom	39	36	--										
	Red					Dark red	1	Ditto	Dark red	17	Ditto	10.9	None	None	10.9

1/ Average of four 5-pound samples taken from two packed boxes; one box inoculated, one box non-inoculated
2/ No difference in color between comparable lots from two cars.
3/ Number of decayed fruits showing in face of pack-two boxes.

Table 6. Condition of Bing cherries in test boxes shipped in Test 3, Stockton to New York

Car	Test Fruit	Fruit temperatures at unloading F°				1st inspection. After 8 hours.			2nd inspection. 36 hours after unloading			Average percent decay 1/			
		Position	Doorway	Quarter length	Bunker	2/ Fruit color	Condition 3/ Fruit	Stems	Fruit color	Condition 3/ Fruit	Stems	Brown rot	Green mold	Rhizopus	Total
P.F.E. 668 Carbon dioxide	Red	top	46	43	42	Dark red	0	Green Fresh	Reddish dark	1	Green wilted	1.8	None	None	1.8
		bottom	42	39	--										
	Red inoculated					Ditto	0	Ditto	Ditto	4	Ditto	1.8	None	None	1.8
REX-362 check untreated	Red	top	46	49	48	Dark red	0	Green Fresh	Reddish Dark	0	Green Wilted	4.9	None	None	4.9
		bottom	41	43	--										
	Red inoculated					Ditto	0	Ditto	Ditto	3	Ditto	8.7	None	None	8.7

1/ Average of two 5-pound samples taken from 1 packed box.
2/ No difference in color between comparable lots in two cars.
3/ Number of decayed fruits showing in face of pack.

Table 7. Condition of Bing cherries in test boxes shipped in Test 4, Stockton to New York

Car	Test Fruit	Fruit temperatures at unloading °F: Position	Doorway	Quarter length	Bunker	1st inspection After 8 hours: 2/ Fruit color	Condition: 3/ Fruit	Stems	2nd inspection. 36 hours after unloading: Fruit color	Condition: 3/ Fruit	Stems	Average percent decay 1/: Brown rot	Green mold	Rhizopus	Total
M.P. 3208 Carbon dioxide	Dark	top	45	46.5	43	Reddish dark	3	Green fresh	Reddish dark	10	Green fresh	12.8	.1	None	12.9
		bottom	38	40	--										
	Red					Red	0	Ditto	Red	0	Ditto	1.1	None	None	1.1
M.P. 3201 check untreated	Dark	top	45	50	45.5	Reddish dark	7	Green fresh	Reddish dark	9	Green fresh	21.5	.6	None	22.1
		bottom	40	42	--										
	Red					Red	0	Ditto	Red	0	Ditto	1.7	.1	.1	1.9

1/ Average of four 5-pound samples taken from two packed boxes; one box inoculated, one box non-inoculated.
2/ Very slightly redder fruit in "darks" from CO_2 car. Definitely redder fruit in "reds" from CO_2 car.
3/ Number of decayed fruits showing in face of pack-two boxes.

Table 8. Condition of Black Tartarian cherries in test boxes shipped in Test 5, San Jose to New York

Car	Test Fruit	Fruit temperatures at unloading °F: Position	Doorway	Quarter length	Bunker	1st inspection After 8 hours: 2/ Fruit color	Condition 3/ Fruit	Condition Stems	2nd inspection. 36 hours after unloading: Fruit color	Condition 3/ Fruit	Condition Stems	Average percent decay 1/: Brown rot	Green mold	Rhizopus	Total
P.F.E. 785 Carbon dioxide	Dark	top	43.5	44	45	Reddish dark	0	Green fresh	Dark	4	Green fresh	11.8	None	None	11.8
		bottom	37	--	--										
	Dark inoculated					Ditto	1	Ditto	Ditto	1	Green wilted	9.3	.6	None	9.9
M.P. 3363. check untreated	Dark	top	47	53	51	Reddish dark	1	Green fresh	Dark	9	Green fresh	38.1	None	None	38.1
		bottom	43	--	--										
	Dark inoculated					Ditto	0	Ditto	Ditto	2	Green wilted	17.4	1.2	None	18.6

1/ Average of two 5-pound samples taken from 1 packed box.
2/ Faced fruit in CO_2 car was slightly redder.
3/ Number of decayed fruits showing in face of pack.

Table 9. Auction Prices of Comparable Lots
in Test Cars - Shipped from Stockton - 5/21/41
Sold New York - 5/26/41

Ranch pack			Row	REX 362 - Check Shipper A		PFE 668 - CO_2 Shipper B	
Grower	Variety	Package	Size	No. boxes	Price	No. boxes	Price
4	Bing	Camp.	11	2	2.15	1	2.55
4	"	"	11 1/2	21	1.85	9	2.70
4	"	"	12	8	1.75	2	2.35
6	"	"	11	1	2.60	1	2.55
6	"	"	11 1/2	25	2.40	21	2.70
5	"	"	11 1/2	6	2.25	9	2.50
5	"	"	12	15	2.25	33	2.50
5	"	"	12 1/2	14	2.20	8	2.40
7	Tarts	S.J.	13 1/2	1	1.25	1	1.50
7	"	"	14	7	1.25	5	1.50
7	"	"	14 1/2	7	1.20	5	1.35
7	"	"	15	6	.90	2	1.25
8	"	"	14	2	.95	1	1.20
8	"	"	14 1/2	56	.95	68	1.40
Weighted Averages				Total	Aver. Price per box	Total	Aver. Price per box
Campbell Lugs	Bings		11	3	2.30	2	2.55
	"		11 1/2	52	2.16	39	2.65
	"		12	23	2.07	35	2.49
	"		12 1/2	14	2.20	8	2.40
San Joaquin Lugs	Tarts		13 1/2	1	1.25	1	1.50
	"		14	9	1.18	6	1.45
	"		14 1/2	63	.98	73	1.40
	"		15	6	.90	2	1.25

Table 10. Auction Prices of Comparable Lots in Test Cars
Shipped from Stockton - 5/23/41
Sold in New York - 5/28/41

Ranch pack Grower	Variety	Package	Row Size	MP - 3208 - CO_2 Shipper A		MP - 3201 - Check Shipper B	
				No. boxes	Price	No. boxes	Price
1	Bing	Camp.	11½	1	2.65	2	2.65
1	"	"	12	7	2.45	4	2.40
1	"	"	12½	2	2.30	2	2.40
2	"	"	11½	2	2.75	1	2.40
2	"	"	12	8	2.65	7	2.40
2	"	"	12½	8	2.50	9	2.35
3	"	"	11½	8	2.80	4	2.55
4	"	"	11½	11	2.80	6	2.65
4	"	"	12	26	2.70	18	2.55
5	"	"	11½	9	3.00	25	2.65
5	"	"	12	35	2.75	6	2.60
Weighted Averages				Total	Aver. Price per box	Total	Aver. Price per box
Campbell Lugs	Bings		11½	31	2.85	38	2.63
	"		12	76	2.70	35	2.51
	"		12½	10	2.46	11	2.36

Table 11. Results of holding tests with Black Tartarian and Bing cherries in CO_2 to simulate transit conditions.
All samples held for 9 days at 42° F.

Test No.	Storage Atmosphere	Color When Packed	After 9 days at 42° F.			2 additional day at room temp.			Remarks
			Color	Firmness	% Decay	Color	Firmness	% Decay	Cond. of sound fruit
1 Stockton 5/14/41 Tart.	Air - check	lt. red	med. red	mod. firm	0	med.dk.red	rather soft	53	Inferior to CO_2 lot
		med. red	dk. red	rather soft	5	dk. red	soft	41	Rath.dull appearance
	CO_2 1/ 23.2%--7.8%	lt. red	lt. red	firm	0	med. red	mod. firm	16	Better than air sample
		med. red	dk. red	mod. firm	1	dk. red	soft	86	Firmer, brighter than check
2 Santa Clara 5/17/41 Tart.	Air - check	lt.md.rd	med. red	mod. firm	2	dk. red	rather soft	65	Sim. to CO_2 sample
		md.dk.rd	dk. red	rather soft	33	dk. rd.blk.	rather soft	87	
	CO_2 16.3%--6.0%	lt.med.rd	med. red	mod. firm	11	med. red	rather soft	69	
		dk. red	dk. red	rather soft	33	dk.red.blk.	rather soft	98	
4 Stockton 5/23/41 Bing	Air - check	lt. red	med. red	mod. firm	3	med.dk.red	rather soft	3	
		med.dk.rd.	dk. red	mod. firm	15	dk. red	rather soft	36	
	CO 17.4%--5.8%	lt. red	med.red 2/	firm	0	med. red	firm	5	Too green for good qual.
		med. red	med.dk.red	firm	0	dk. red	mod. firm	19	Firmer than air samp.
5 Santa Clara 5/23/41 Tart.	Air - check	med. red	med. red	rather soft	24	dk. red	soft	42	Unmarketable
		dk. red	dk. red	soft	30	black	soft	46	Unmarketable
	CO_2 10.2%--5.5%	lt. red	lt.med.rd	mod. firm	8	dk. red	rather soft	40	Firmer than air
		dk. red	dk.red 3/	rather soft	7	dk. red	soft	48	sample; Firmer, less color than check
5/30/41 Bing	Air - check	lt. red	med. red	mod. firm	2	med. red	mod. firm	46	Darker, less firm than CO_2 s. Darker, softer than CO_2 sample.
			dk. red	mod. firm	2	dk. red	mod. firm	61	
	CO_2 18.0%--5.5%	lt. red	med. red	firm	0	med. red	mod. firm	64	Perf. cond. after 9 da
		med. red	dk. red	firm	0	dk.rd.blk.	firm	73	Excellent condition
6/3/41 Bing	Air - check	med. red	med. red	firm	2	dk. red	mod. firm	30	
		dk. red	dk. red	firm	10	dk. red	mod. firm	68	
	CO_2 22% -- 4%	med. red	med. red	firm	0	med. red	firm	42	Brighter than air s.
		dk. red	dk. red	firm	5	dk. red	mod. firm	34	Less decay than chk.

1/ Charged 5/15, 2nd day 23.2%, 3rd day 12.8%, 4th to 8th day 10%, 9th day 7.8%.
2/ Slightly lighter color than check.
3/ Fewer black fruits than check.

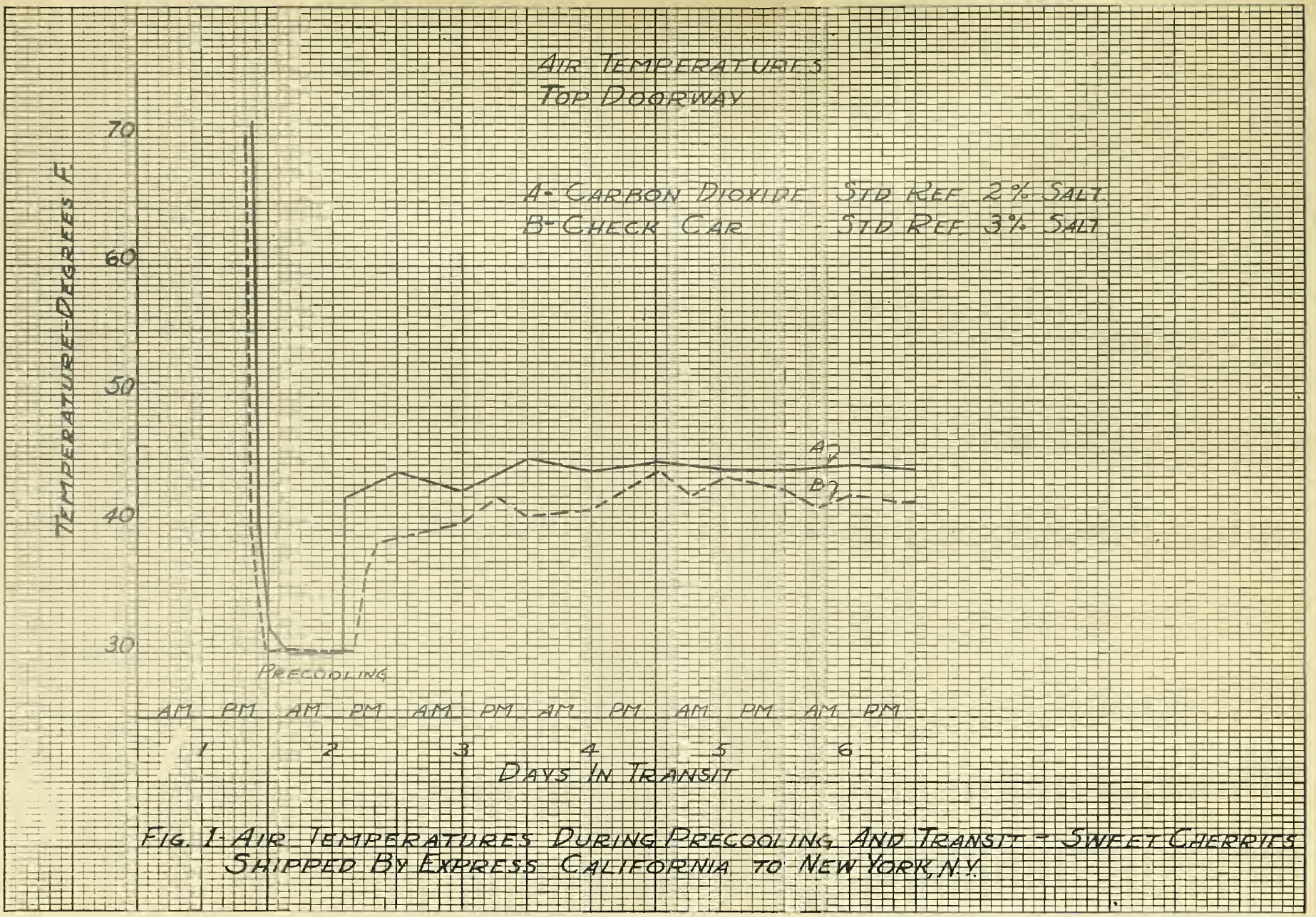

FIG. 1- AIR TEMPERATURES DURING PRECOOLING AND TRANSIT - SWEET CHERRIES SHIPPED BY EXPRESS CALIFORNIA TO NEW YORK, N.Y.

TEST 1, 1941

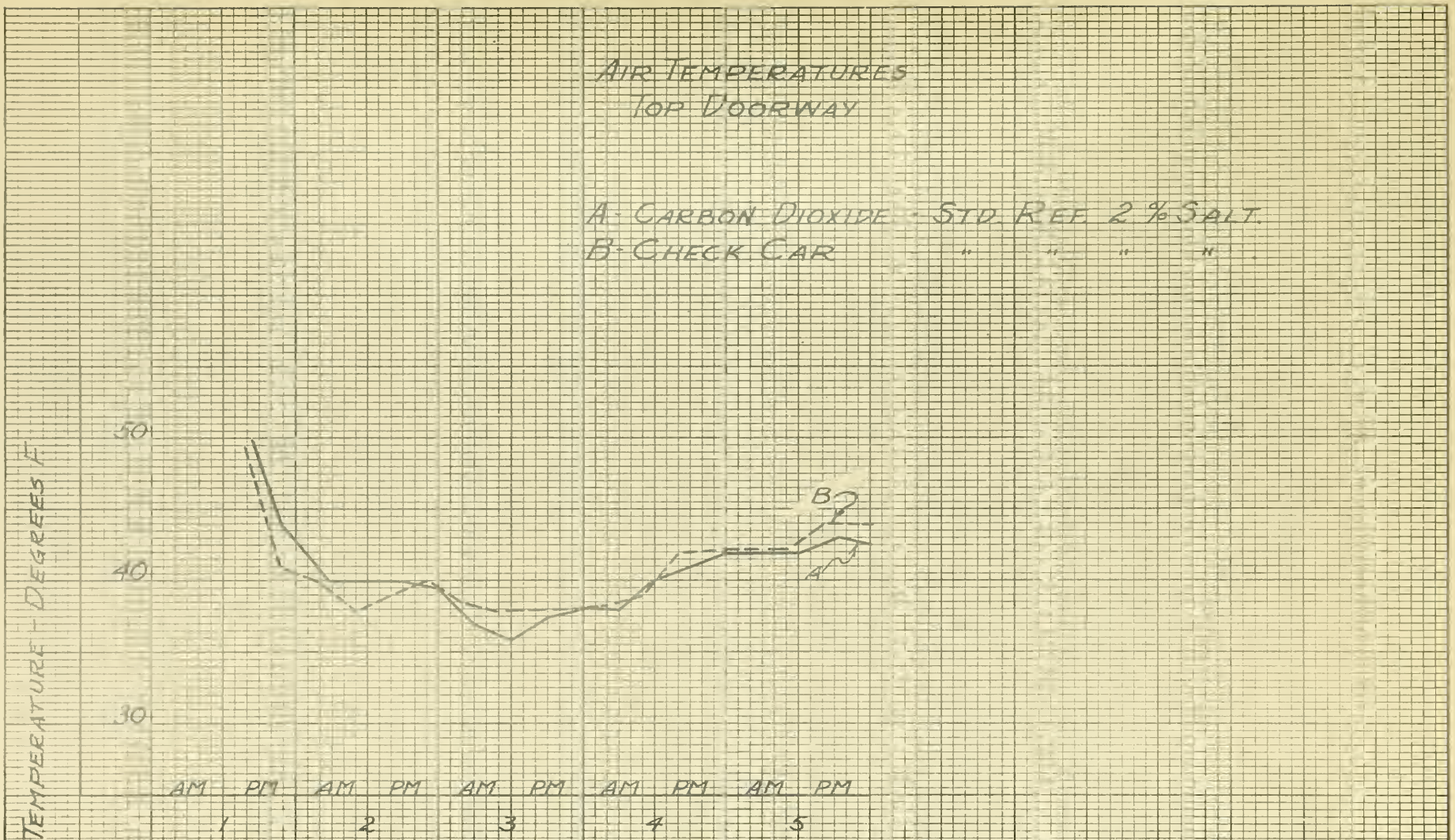

FIG. 2 - AIR TEMPERATURES DURING TRANSIT - SWEET CHERRIES SHIPPED BY EXPRESS. CALIFORNIA TO NEW YORK, N.Y.

TEST 2, 1941

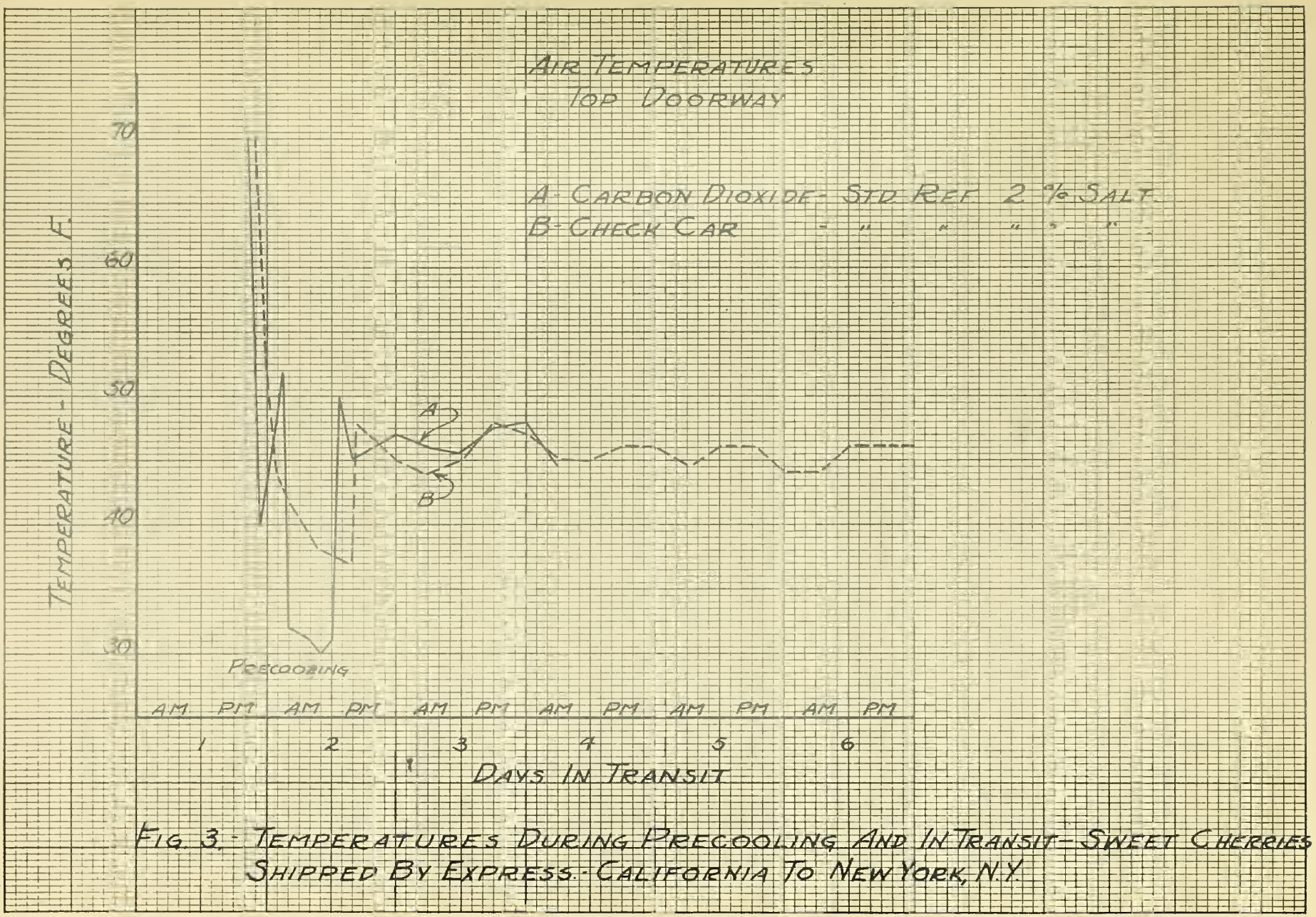

FIG. 3. - TEMPERATURES DURING PRECOOLING AND IN TRANSIT - SWEET CHERRIES SHIPPED BY EXPRESS. - CALIFORNIA TO NEW YORK, N.Y.

TEST 3, 1941

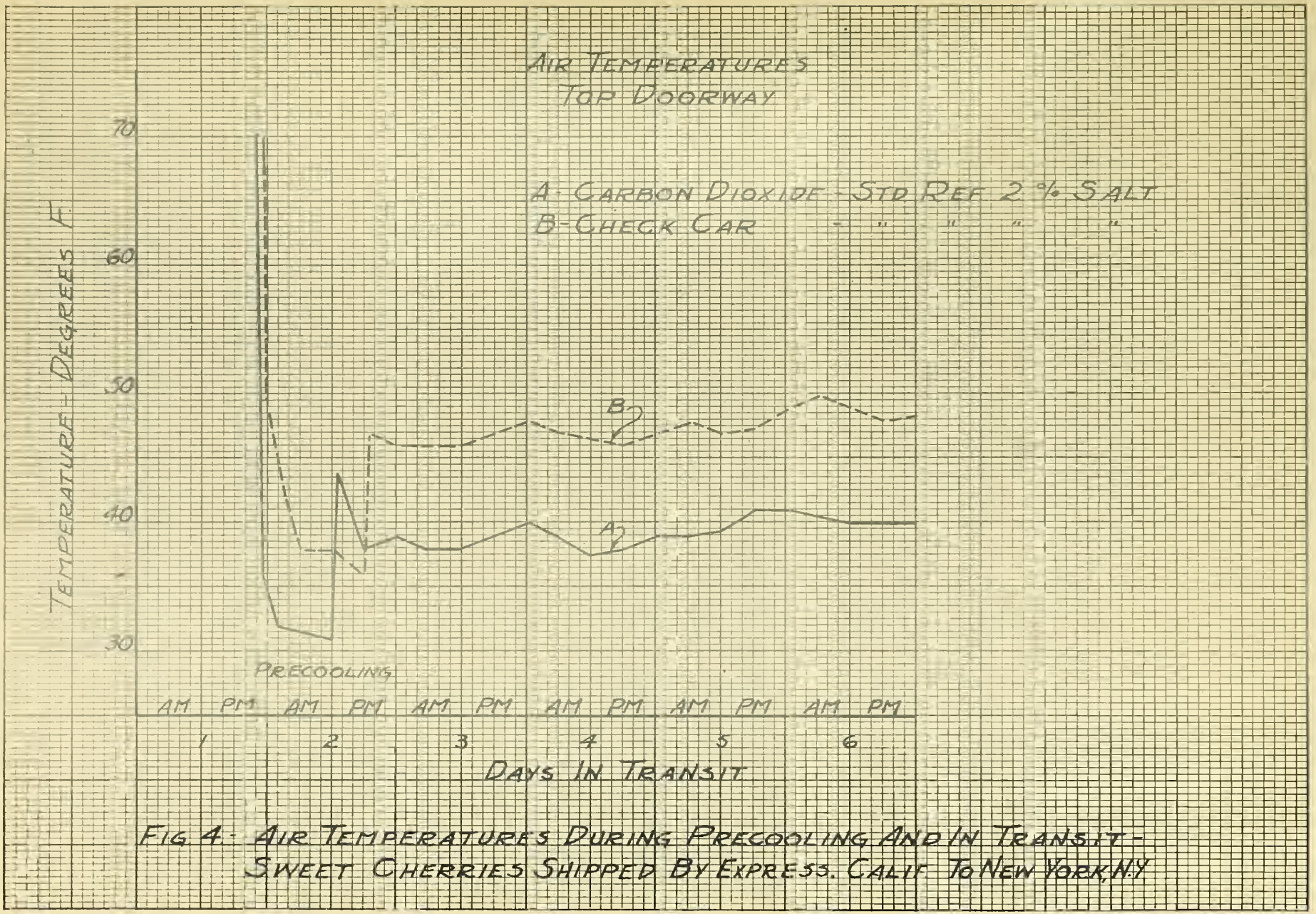

FIG. 4: AIR TEMPERATURES DURING PRECOOLING AND IN TRANSIT - SWEET CHERRIES SHIPPED BY EXPRESS. CALIF. TO NEW YORK, N.Y.

TEST 4, 1941

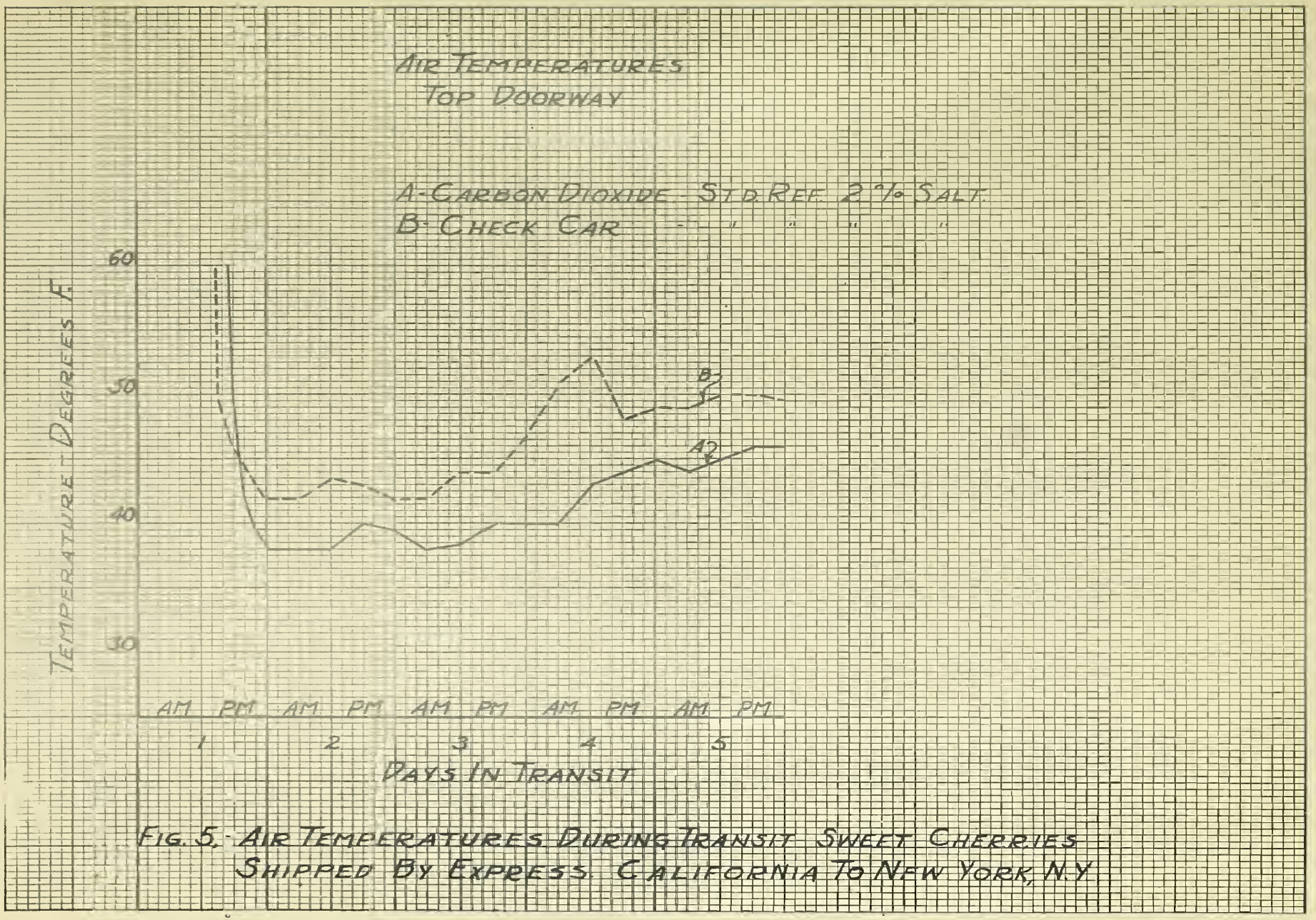

FIG. 5. - AIR TEMPERATURES DURING TRANSIT SWEET CHERRIES SHIPPED BY EXPRESS. CALIFORNIA TO NEW YORK, N.Y.

TEST 5, 1941